ENVIRONMENTAL AND WASTE MANAGEMENT: ADVANCEMENTS THROUGH THE ENVIRONMENTAL MANAGEMENT SCIENCE PROGRAM

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PHYTOREMEDIATION OF METAL-CONTAMINATED SOILS

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INTRODUCTION

Recent concerns regarding the environmental contamination have necessitated the development of appropriate technologies to assess the presence and mobility of metals in soil and estimate possible ways to allow the decrease of the level of soil metal contamination. Phytoremediation is an emerging technology that may be used to clean-up contaminated soils[1]. Successful application of phytoremediation, however, depends upon various factors which must be carefully investigated and properly considered for specific site conditions[2].

In our research, to efficiently affect the metal removal from contaminated soils we used both the ability of plants to accumulate different metals and agricultural practices that make possible improving the soil quality and enhancement of plant biomass. Pot experiments were conducted to study metal variations in the soil and stimulate transfer of the metals to more available for plants form. The purpose of the experimental study was also to find fertilizers that could enhance mobility of metals in soil.

MATERIALS AND METHODS

Greenhouse pot experiments were performed in August – September 2002. Soil was sampled in two sites: contaminated soil was taken near road with heavy traffic and clean soil was taken from park protected from the road by buildings. Seedlings of wheat

Triticum vulgare, sort *Umanka* were grown in the soils for 36 days and harvested three times – within 3, 14 and 36 days after planting. Three fertilizers (urea, horse manure and "ispolin" - fertilizer on the basis of mixture of organic fertilizers, humic acids, livestock and industrial population of worms) were used to improve soil quality and to affect metal mobility in the soils. Soil samples from surface of the plant roots (the rhizosphere soil) were taken simultaneously with the plants. The initial clean and contaminated soils were used as a basis to estimate variations in chemical parameters of the soils. Control plants grown in the contaminated and clean soils were compared with the plants grown in the soils amended with the three fertilizers. Microwave assisted nitric acid digestion combined with ICP-MS/ICP-AES techniques were used to determine concentrations of Ag, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, S, Sb, Se, Sr, Th, Ti, Tl, U, V and Zn in roots and leaves of the plants and in the soils. Statistical treatment of the experimental data included the estimation of mean concentrations of the elements and differences between groups of the samples (Statistica for Windows 5.5).

RESULTS AND DISCUSSION

Concentrations of Ag, Cd, Cu, Pb, Sb and Zn in the initial contaminated soil were 3 – 6 times higher than those in the initial clean soil. Elemental compositions of the plants grown in the clean and contaminated soils were also very different. In particular, contents of Cu, Mo, Ni, Pb, Sb and Zn in roots of the wheat grown in the contaminated soil were higher ($P<0.01$) than those in the roots of the plants grown in the clean soil. Moreover, all the elements except Pb transferred more easily from roots to leaves. Differences between concentrations of the elements in leaves of the wheat grown in the clean and contaminated soils were statistically significant at $P<0.01$.

The principal component analysis of the element concentrations of the plant samples showed that leaves were clearly separated from roots by the first factor (Fig. 1). There were also well-marked differences between plants sampled on first date and plants sampled on two other dates. To exclude the effect of sampling date, thereafter we used only the analytical data of plants sampled on two last dates (Fig. 2). In this case the plants grown in soil fertilized with "ispolin" were clearly separated by the PC3 from the plants grown in non-amended soil and soil amended with urea and manure. Roots and leaves of the plants grown in the clean and contaminated soils were separated into two groups by the PC2.

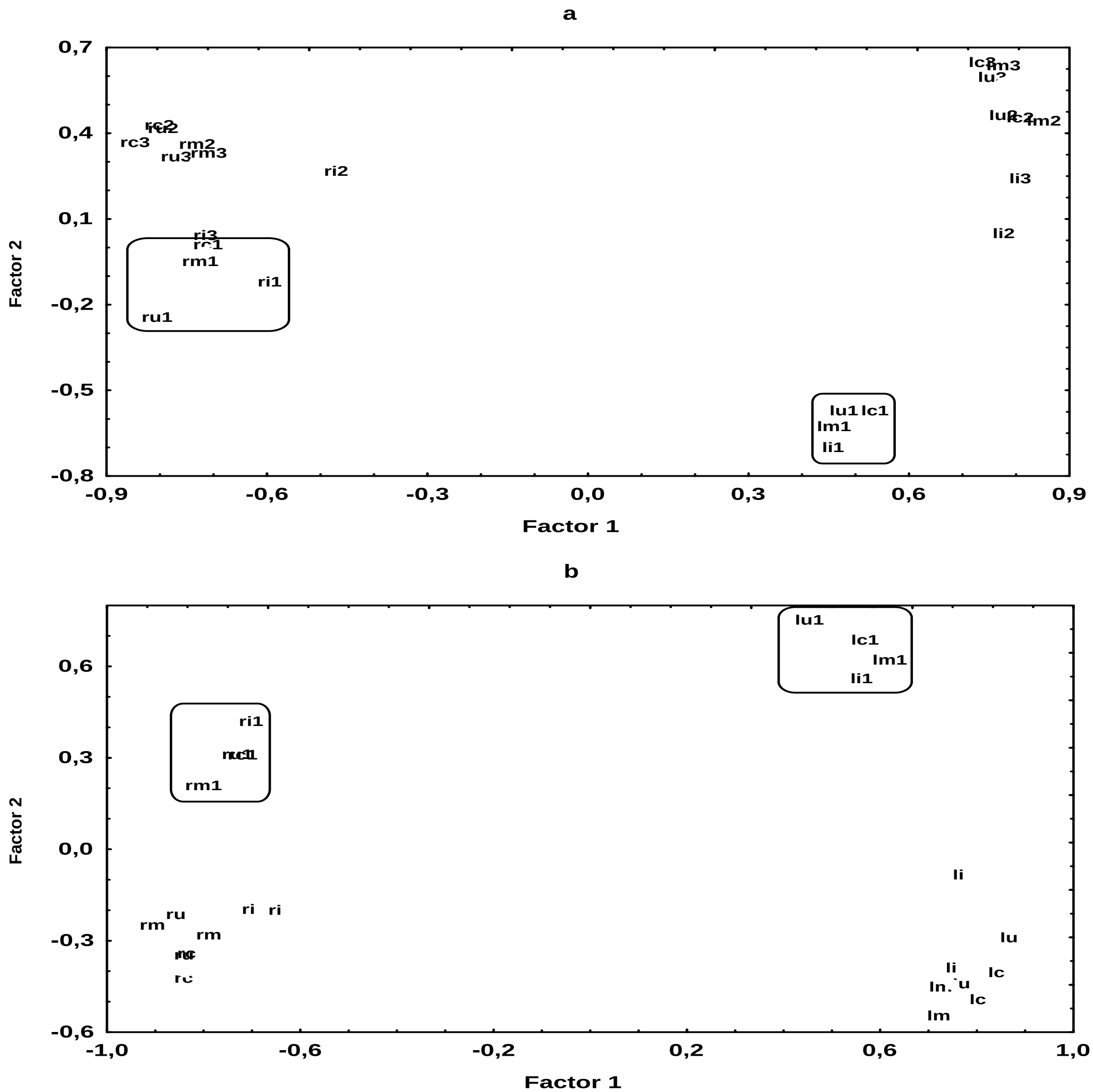

Figure 1. Score plot of the two first principal components of plant samples grown in clean (a) and contaminated (b) soil. ru, rm, ri and rc – roots of the plants grown in soil fertilized with urea, manure, ispolin and control (non-fertilized) soils, respectively. lu, lm, li and lc – leaves of the plants grown in soil fertilized with urea, manure, ispolin and control (non-fertilized) soils, respectively. 1, 2, 3 – first, second and third dates of sampling.

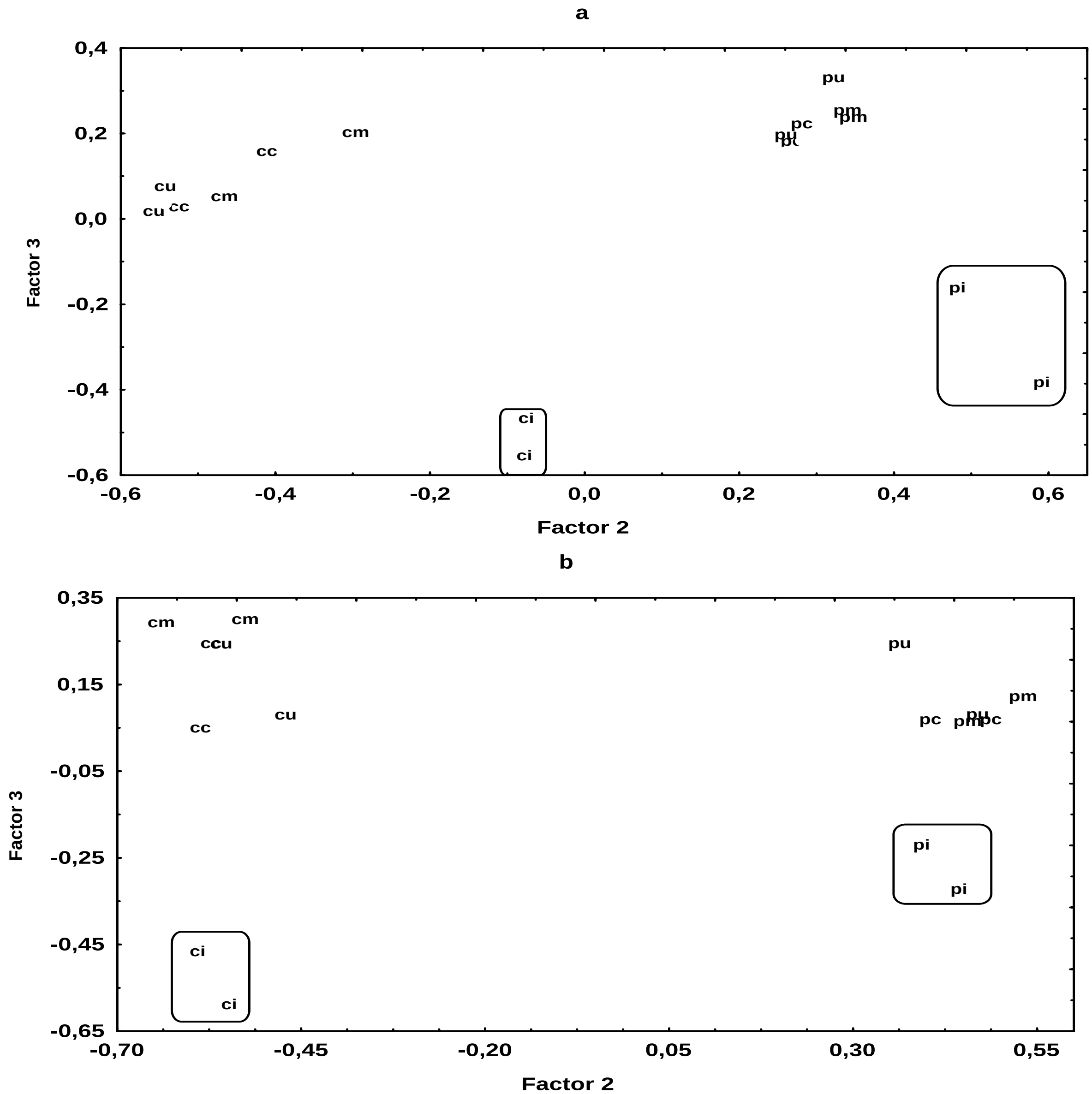

Figure 2. Score plot of the second and third principal components of leaf (a) and root (b) samples. The plants were grown in clean non-fertilized (cc), fertilized with urea (cu), manure (cm) and “ispolin” (ci) soil and in contaminated non-fertilized (pc), fertilized with urea (pu), manure (pm) and “ispolin” (pi) soil.

Cultivation of wheat as fast growing plants resulted in variations in concentrations of several macro- and trace elements in the soils. The response to the wheat growth was site-specific and mainly concerned essential nutrients such as B, K, Na, P, S and Sr. Besides, in comparison with initial soil, concentration of Cd in cultivated contaminated soil decreased 1.4 times (the differences in Cd content between the initial and cultivated soils were significant at $P<0.05$). Concentrations of other toxic metals in the soils remained unchanged. The response to applying the fertilizers was also site-specific and resulted in variations in concentrations of several nutrients in the soils. This had the effect of improving the physiological state of the plants growing in the fertilized soils. In particular, manure and “ispolin“ provided a significant increase in leave and root biomass of the plants grown in contaminated soil as compared to the control plants grown in the non-amended contaminated soil. Amendment of the contaminated soil with urea and manure showed a decrease of Al, Cd and Zn concentrations in the soil (Table 1). The best effect was demonstrated after application of “ispolin“: over a short period (36 days) concentrations of Al, Cd, Cu, Pb and Zn in the soil decreased 1.2 – 1.4 times in comparison with those in the initial contaminated soil. Probably, this was result of combined effect of root exudates and release to the soil specific organic compounds produced by the fertilizers.

Table 1. Effects of wheat cultivation and application of different fertilizers on concentrations of metals in contaminated soil (concentrations of metals are presented as mg kg^{-1}). *, ** differences between element concentrations in the initial and experimental soils are significant at $P<0.05$ and $P<0.01$, respectively.

Metal	Without fertilizers		Wheat plus fertilizers		
	Initial soil	Wheat (control)	Urea	Manure	Ispolin
Al	7790±525	6627±1006	6207±426**	6373±722*	6140±644**
Cd	2.4±0.5	1.7±0.4*	1.3±0.4**	1.6±0.6	1.4±0.4**
Cu	175±31	164±39	151±19	169±15	143±14*
Pb	205±38	170±42	155±47	169±33	143±21*
Zn	565±45	507±178	555±188	426±79*	404±72**

ACKNOWLEDGEMENTS
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